

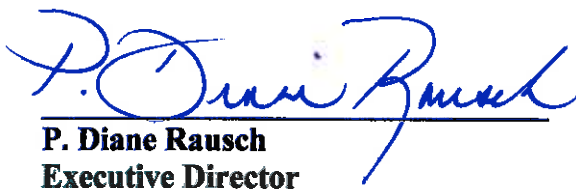
**National Aeronautics and Space Administration
Washington, DC**

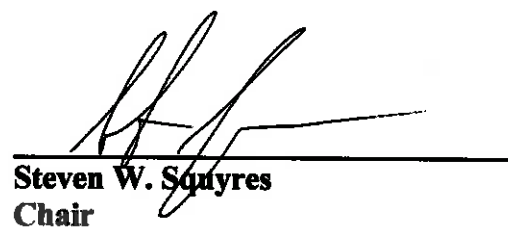
NASA ADVISORY COUNCIL

April 16-17, 2014

**NASA Headquarters
Washington, DC**

MEETING MINUTES


P. Diane Rausch
Executive Director


Steven W. Squyres
Chair

**NASA ADVISORY COUNCIL
NASA Headquarters
Washington, DC
April 16-17, 2014**

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***Meeting Report prepared by
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**NASA ADVISORY COUNCIL
NASA Headquarters
Washington, DC**

**PUBLIC MEETING
April 16-17, 2014**

MINUTES

Wednesday, April 16, 2014

Call to Order and Announcements

Ms. Diane Rausch, Executive Director, NASA Advisory Council (NAC or Council), NASA Headquarters (HQ), called the meeting to order and welcomed the NAC members and attendees to NASA HQ in Washington, DC. She stated that the NAC is a Federal advisory committee established under the Federal Advisory Committee Act (FACA). The meeting is open to the public. All comments and discussions should be considered to be on the public record. A dial-in capability is available for members of the public to listen to the meeting. WebEx is also available. Meeting minutes will be prepared and will be posted to the NAC web site, www.nasa.gov/offices/nac, soon after the meeting. She noted that each NAC member has been appointed by the NASA Administrator, Mr. Charles F. Bolden, Jr., based on the member's individual subject matter expertise. Each member is a Special Government Employee, subject to ethics laws, and must recuse himself or herself from discussions on any topic where there could be a potential conflict of interest. Questions about ethics issues should be brought to her attention immediately and, if needed, she will arrange a meeting with an ethics attorney from NASA's Office of General Counsel (OGC). Time has been set aside on the meeting's first day for public comments.

Opening Remarks by Council Chair

Ms. Rausch introduced Dr. Steven Squyres, Chair, NASA Advisory Council. Dr. Squyres explained that he has been looking forward to this meeting. To the new members recently appointed to the Council, he expressed his appreciation for their willingness to serve. The new members are Dr. Wanda M. Austin, Member at Large, President and CEO, the Aerospace Corporation; Mr. N. Wayne Hale, Member at Large, Consultant, Special Aerospace Services of Boulder, Colorado and NASA (Ret.); Prof. G. Scott Hubbard, Member at Large, Department of Aeronautics and Astronautics, Stanford University and former Director, NASA Ames Research Center; Mr. A. Thomas Young, Member at Large, Lockheed Martin (Ret.), former Director, NASA Goddard Space Flight Center (GSFC); Mr. Miles O'Brien, Member at Large, independent journalist; and Ms. Kathryn Schmoll, Chair of the new Institutional Committee, Vice President, Finance and Administration, University Corporation for Atmospheric Research (UCAR). He noted that Prof. Hubbard's wife, Susan, had just passed away and he expressed condolences on the Council's behalf.

Dr. Squyres described recent changes made to the Council's structure and process. In the past, the Council primarily consisted of Dr. Squyres and the NAC Committee Chairs. As a result, the time was mostly devoted to discussing matters from the committee perspective, which was necessary but not sufficient. At Mr. Bolden's urging, a NASA internal review had been undertaken during Fall 2013 by NASA's Chief Engineer, Chief Scientist and Chief Technologist (known as the "Three Chiefs"). As a result of this study, NASA Administrator Bolden decided to reduce the number of NAC committees from eight to five, and add a number of at-large members. This will reduce the amount of time the NAC spends on specific committee matters, allowing room for more strategic, crosscutting discussions with the additional at-large members, thereby enabling the Council to have meaningful deliberations about the broader policy and programmatic issues that affect the Agency. The NAC agendas, in addition to committee reports, will now have more time for thoughtful discussion and deliberation. Council members are encouraged during those discussion periods to bring up any issues that merit discussion, whether or not the issue is on the agenda. NAC Findings and Recommendations will now come in two "flavors." One is where an issue does not cut across the whole Agency or does not need the NASA Administrator's immediate attention and is intended instead for a specific Associate Administrator (AA). The other is where an issue does cut across the entire Agency

or deserves the Administrator's immediate attention. Another recently added agenda item remains a favorite of Dr. Squyres and will continue to be included in Council meetings – the opportunity to have a young early career engineer or scientist, a “hotshot” come in to describe what they are working on at NASA. NASA Center Directors are challenged to bring in their best up and coming stars. Dr. Squyres reminded everyone that he is rigorous about keeping the NAC meetings on schedule. He noted that the NASA Administrator just gave him a 2014 NAC Work Plan covering important issues the Administrator wants the Council to consider during calendar year 2014. This does not preclude the NAC consideration of other issues, but is a focal point for the NAC deliberations in the coming year. Copies of the 2014 NAC Work Plan were distributed to Council members by Ms. Rausch.

Remarks by NASA Administrator

Dr. Squyres then introduced Mr. Charles Bolden, NASA Administrator. Mr. Bolden welcomed everyone in the room to NASA Headquarters in Washington, DC. He noted that it was the NAC's first meeting in 2014, that it is the first meeting of the “new NAC,” and that there is a lot going on in the Agency and in Washington, DC, because it is budget season. He described the process that was used to establish the “new NAC.” He had asked NASA's Chief Scientist, Chief Engineer, and Chief Technologist to examine the NAC's current mode of operation and internal workings and then, using their knowledge of Agency issues and challenges, determine how the Council could be improved in order to provide more strategic, cross-cutting advice. When Mr. Bolden became NASA's Administrator in 2009, the NAC was very different organization and much larger than it is today. There were some 52 committee members and each was also a Council member. That was far too large and cumbersome. Therefore he made the decision shortly after his arrival to streamline the Council through reorganization to make it more efficient. Some committees were decommissioned and some were added. The NAC operated under that structure for four years. Last Fall, at his request the NAC's structure was re-examined with the intent to enable it to be more cross-cutting across the Agency by adding members who did not have “stove-piped” responsibilities that focused on specific areas. Last November, he announced the new NAC reorganization. Since the announcement of his decision to reorganize the NAC, there has been more discussion about the NAC's structure. Every decision made by the NASA Administrator, Mr. Bolden quipped, seems to be the beginning of a discussion, not the end.

Mr. Bolden welcomed six newly appointed Council members: Dr. Austin, Prof. Hubbard, Mr. Hale, Mr. Young, Mr. O'Brien, and Ms. Schmoll. Each person is absolutely exceptional in what they do and have accomplished great things in their careers. He explained that he wants strong-willed people for this Council and that he is willing to take criticism. He noted that, “If I can't take the heat, then I need to get out of the kitchen.” Dr. Bolden also welcomed back the returning Council members: Ms. Marion Blakey, Dr. William Ballhaus, Dr. David McComas, Dr. Charles Kennel, Gen. Lester Lyles, and Mr. Ken Bowersox. He thanked them again for continuing to accept the challenge and promised to take the Council's findings and recommendations very seriously. Last year, he noted, the NAC produced 25 recommendations and 25 findings, and NASA formally responded back to the NAC with comments on each. One challenge he has given the NAC is to advise on five critically important key areas of interest that are described in what he refers to as the NAC 2014 Work Plan. The five key areas are:

- Overhauling NASA's Information Technology (IT) Governance Structure, and Ensuring the Security of NASA's IT Systems
- Acquisition Reform, and Ensuring the Integrity of the Contracts and Grants Process
- Capability Driven Framework for Future Human Exploration
- Human and Robotic Mission Cooperation
- Knowledge Capture

He explained that the reason behind the Capability Driven Framework is to help ensure that NASA is on the right path. NASA knows where it is going and knows that it does not have all the tools to get there, so step by step it will gain the necessary new capabilities.

Mr. Bolden explained that the NAC's meeting is a public forum and that he welcomes the transparency that the meeting brings. He counseled the members not to worry that their comments will be parsed, rephrased, and used to suit other people's purposes. He knows that it goes with the territory and it is not going to bother him. He looks forward to hearing the members' perspectives and their formal findings and recommendations. He invited them to dive deeply for all the information that is needed and to have a lively debate. They should not hesitate to ask NASA to bring people in to clarify anything. Before acting on something thought to have been said by a NASA official, he

advised that the Council should ask that official to come talk to them. He believes that the Council's thoughtful advice will position NASA for higher levels of achievement in years ahead. He added that he hopes that the Council members will have an opportunity to meet the Three Chiefs.

Mr. Bolden described recent events at NASA since he last met with the Council in December 2013 at NASA's Kennedy Space Center (KSC). There has been a FY 2014 appropriation and the FY 2015 President's Budget Request had been released. Overall, NASA is in good shape with the numbers. The President's Budget Request ensures that the U.S. will remain a leader in scientific exploration and discovery for years to come. The Budget Request confirms a bipartisan agreement and keeps NASA on the path to meet the President's challenge to send humans to Mars in the 2030s. Mr. Bolden recalled that when the President Obama visited KSC in Florida in April 2010, he gave a major space policy speech challenging NASA to send a human to an asteroid by 2025 and to Mars in the 2030s. NASA took that challenge very seriously. NASA has unveiled its *2014 Strategic Plan* that includes growing the U.S. commercial space industry. Based on Congressional hearings he has attended, Mr. Bolden believes that Congress understands the importance of the Asteroid Redirect Mission, in which humans will be sent to an asteroid. Under the President's Opportunity Growth and Technology Initiative, NASA will receive \$815 million (M) in additional funds across its portfolio that will be used to buy down risks. The current situation in the Ukraine will not affect NASA's joint operations with Russia on the International Space Station (ISS), nor will it prevent U.S. scientists from attending the international space research conference to be conducted this summer in Moscow by the Committee on Space Research (COSPAR). The situation does, however, highlight the pressing need to help the commercial partners develop the ability to launch astronauts to low-Earth orbit (LEO). The SpaceX Dragon spacecraft will carry 2.4 tons of cargo to the ISS for Expeditions 39 and 40. Robonaut 2, the robotic crew member, will receive "high-tech legs" that will enable it to help with repetitive tasks inside the ISS. Orbital Sciences is planning its next launch in early May. The ISS is a busy place and has traffic jams due to the many flights to it. There are now six or seven different visiting vehicles. Mr. Mike Suffredini and the Space Station Program in Houston are doing a tremendous job. Commercial space is repeatedly demonstrating its value. It is a good investment for the American public and instrumental for a future mission to Mars. An agreement has been entered to allow SpaceX to use Launch Complex 39A at KSC, which is the pad from which Mr. Bolden took his first flight into space. The agreement with SpaceX is a tangible example that KSC is transforming into a 21st Century Spaceport. Mr. Bolden described how students in an elementary school class discovered four new asteroids.

Mr. Bolden explained that the Asteroid Retrieval Mission (ARM) is helping NASA develop new technologies like solar electric propulsion (SEP) that will be needed for a deep space mission to Mars. It is important, he noted, to be careful about how this initiative is characterized. NASA is not saving the planet with this mission. This mission will provide information on the Nation's ability to perhaps save the planet. The ARM will demonstrate that NASA can affect an asteroid's path. The Commercial Crew Program (CCP) will help NASA move beyond Low Earth Orbit (LEO). The Space Launch System (SLS) and the Orion Multi-Purpose Crew Vehicle (Orion or MPCV) are needed to take humans into deep space. Commercial spacecraft cannot be depended upon for deep space exploration because the required launch frequency adds too much risk. NASA is on the right path as long as cost and schedule can be maintained in the capability driven approach. A more optimal process would be available if cryogenic storage was available for fuel deployment in space. Developing that capability would require time and money that is not available. Mr. Bolden invited the Council to discuss this in its deliberations. He noted that the first flight test for Orion will take place later this year. Orion is the first spacecraft designed to bring people into deep space that has been built by the U.S. in over 40 years. No one else is doing this. People are depending on the U.S. for leadership. NASA is relying more and more on industry as it always has done, and is also dependent on international partners to supply components.

The Exploration Design Challenge was described by Administrator Bolden. It challenged students to develop ideas for shielding astronauts on Orion from radiation. The winners will be announced next week. Over 35,000 students submitted responses in the first week and that number is now over 100,000. The top five students will be flown to KSC for the launch and the top design will be flown onboard as a test. Mr. Bolden observed that the ISS continues to be the springboard to the rest of the Solar System. There will be a spacewalk as soon as possible to replace a Multiplexer/Demultiplexer Module (MDM), which is an external computer on the ISS. The President's Budget Request for FY 2015 supports a mission to Europa, a Rover mission to Mars in 2020, and a 2018 launch for the James Webb Space Telescope (JWST). Over the next 18 months, the Space Technology Mission Directorate (STMD) will invest in several high-priority challenges.

In closing, Administrator Bolden awarded the NASA Exceptional Public Service Medal to Dr. Charles Kennel, who is rotating off the Council since his term as Space Studies Board Chair is coming to an end in June 2014. The medal is one of NASA's highest awards for a civilian. Mr. Bolden observed that Dr. Kennel's contributions will benefit the Nation for many generations to come. Dr. Kennel thanked Mr. Bolden for the award. He noted that NASA has been the mainstay of his professional life and he thanked NASA and the Council for a "wonderful ride."

Mr. Bolden expressed his best wishes to the Council members for a successful meeting. He looks forward to getting the Council's advice and recommendations. He encouraged the Council members to enjoy their deliberations and expressed his hope that they find themselves rejuvenated and inspired as they address the difficult and challenging questions that lie ahead.

Dr. Squyres thanked Mr. Bolden for his comments. Questions for Mr. Bolden were deferred until after the next speaker, the President's Science Advisor, Dr. John P. Holdren. Persons following the meeting telephonically were requested by Dr. Squyres to mute their telephones.

The Administration's Vision for NASA

Mr. Bolden introduced Dr. John P. Holdren, the President's Science Advisor and Director, Office of Science and Technology Policy (OSTP), The White House. He noted that Dr. Holdren has been a good friend to NASA and to science and technology. Dr. Holdren thanked Dr. Kennel for his service to NASA and for his leadership during the Obama Administration.

Dr. Holdren expressed appreciation for the opportunity to share the Administration's vision for NASA. NASA is considered to be the point on the global spear for space exploration and Earth observation. He noted that the President put forth in a speech at KSC on April 15, 2010, his vision for the future of U.S. space exploration. That speech remains a good summary of the President's vision for what NASA and the U.S. space program should be about. The President's annual budget requests to Congress reflect his vision for U.S. leadership in space, tempered only by the limited funding available. The Administration's policy has been based on hard looks at the available evidence. That is the best way to ensure that NASA remains on a sustainable path, while getting the best mileage on the U.S. taxpayer's dollars. Dr. Holdren counseled that there is a need to temper ambitions with budgetary realities. He observed that NASA is "20 pounds of mission in a 10 pound budget." People should be encouraged by the steadfastness the President has shown when it comes to supporting the full range of NASA's capabilities. In his role as OSTP Director and the President's Science Advisor, he has the privilege and responsibility of looking across the Agency's broad portfolio. Space exploration is personal for him. He watched Sputnik pass overhead in his youth, and when he was 17 years old, he realized a dream to study aerospace engineering at MIT. His high school senior class trip was to KSC, where he saw the Saturn 5 Vehicle Assembly Building and the crawler. His senior class project at MIT was to design a manned mission to Mars. The President shares the passion and curiosity about space that he feels. He hopes the Administration and the NAC can continue to celebrate and cultivate that interest. NASA has been focused correctly on bringing space launches back to America through the commercial space industry. The new way of doing business, partnering NASA with industry, should not be limited to bringing cargo and crew to LEO. He is pleased, therefore, to hear about more partnerships in deep space exploration. The growing U.S. spaceflight industry improves life on Earth, creates jobs, and improves innovation.

Dr. Holdren commented on the President's FY 2015 Budget Request. NASA's budget total for 2015 is \$17.5 billion (B). Through contributions to commercial launch development it directly supports the U.S. capability. The 2015 budget supports the development of private sector systems, supports ISS through 2024, and decreases the duration of the U.S. sole reliance on Russian space vehicles. It provides for a dynamic space technology development program and an aeronautics program. It includes \$886 M in additional funding for an Opportunity, Growth, and Security Initiative to invest in developing game-changing technologies and bolster research on understanding Earth. The budget allocates \$40 M to enhance capabilities to identify potentially dangerous asteroids that might be deflected, \$2.8 B for NextGen aeronautics, \$5 B for NASA science, \$1.8 B for climate research, and \$645 M for continuing development on the JWST, which will be the successor to the Hubble Space Telescope (HST). Dr. Holdren noted that NASA recently announced the Asteroid Data Hunter Challenge, which tasks competitors to develop improved algorithms to identify asteroids in images from ground-based telescopes. He explained that the budget for FY 2015 affirms the bipartisan agreement between the President and Congress, funds a robust science program, and continues groundbreaking work in technology and aeronautics. Dr. Holdren acknowledged that there was some criticism at the

time that the Administration started in this direction. He believes that even the critics now have to admit that the record is impressive. Creativity and innovation are not limited to the launch industry. New companies are offering SmallSat and NanoSat systems designed to replicate the capabilities of larger, more expensive satellites. There is an opportunity now to unleash the "dot com" moment of space. Think about how enablers might empower an exponential increase in space allowing us to go smaller, faster, further, and smarter. There is a need to triple and quadruple what we do, but that cannot be accomplished by relying on an increase in spending. Next generation technologies like on-orbit refueling and SEP are part of a huge horizon of new technology. Enabling this future must be founded in a set of smarter policies. The interest in this business comes from the desire to seek out the unknown. In conclusion, he noted that it is his pleasure in the White House to convey and nurture that enthusiasm and to be an evangelist for the efforts to reach for the stars. He thanked the Council for its support and cooperation.

Dr. Squyres thanked Dr. Holdren for his comments and explained that this is an extraordinary opportunity to for the Council members to direct questions to the Administrator and to the President's Science Advisor. Gen. Lyles asked Dr. Holdren to share his passion and vision for aviation and aeronautics. Dr. Holdren responded that the Administration is broadly focused on the whole transportation infrastructure. He observed that transport aircraft capabilities have advanced in a manner more impressive than what has been accomplished in the automobile industry. This is attributable, in part, to research led by NASA. The area is a challenge for U.S. Government investments and its importance is recognized by the President. Mr. Bolden advised that there is a need to publicly recognize national priorities. Hypersonics is a fundamental capability in which the U.S. leads the world and is being hotly pursued by other nations. We should bring together the Department of Defense (DoD), the Defense Advanced Research Projects Agency (DARPA), and NASA to determine that this is a national priority, break down the stovepipes, and allow cross-talk.

Dr. Ballhaus recalled his surprise and disappointment on seeing how NASA's investments in technology had been decimated over the years. New funding for that purpose is beginning to pay off. One challenge, however, in the budget environment is the fact that the NASA Small Business Innovation Research and Small Business Technology Transfer programs are included in the STMD budget. Those programs are generally protected from budget cuts. Accordingly, true technology funding suffers when budgets are cut across the board. Mr. Bolden responded that this is not an Administration issue as much as it is a liaison issue between NASA and the Congressional budget committees. NASA is continuing to work with them to help them understand that technology development should be a higher priority in Congress. If there is to be a real exploration program, there needs to be a domestic capability to get astronauts and cargo into LEO so that NASA does not have to do that. NASA is out of the access business for Low Earth Orbit (LEO), which is a decision that was made some time ago. NASA safely transitioned from the Space Shuttle Program and is now transitioning into commercial crew and cargo, but needs to get Congressional support for that. It is a slow, painful process to whittle away at the opposition to what the President knows is very important: technology development. Dr. Holdren explained that there is an education problem in conveying the connection between advanced technology and the ability to perform the missions that Congress wants NASA to accomplish. Much work remains to be accomplished in radiation protection, advanced propulsion, landing capabilities, and increasing data transfer rates with lasers. Congress does not understand that we will not get there without expenditures in advanced technology. That is the education effort that must be undertaken in order to prevent Congressional "fiddling" with budget categories in ways that imperil technology development programs.

Dr. Kennel noted that the Space Studies Board is working with NASA to develop a work statement for the next Decadal Survey in Earth Sciences. The main issue will be a tension between continuity missions that produce data sets needed by scientists for long-term studies and that policy makers need for identifying long-term trends, and new research. There is a "zero-sum game" because the same money must be used to accomplish both goals. The key issue is to find the right balance. Who is going to do what and the roles and missions for the different partner agencies are not as clear as they could be. He asked how the tension will be resolved between new science capabilities and long term commitments. This is a critical time for guidance to be given on how to structure the Earth Sciences Decadal Survey. Dr. Holdren responded that it is his office's responsibility to coordinate the science and technology development activities across U.S. Government agencies. He will ask his staff to increase the effort on this. He added that it is important for everyone to make the argument that the President's proposed \$886 M Opportunity, Growth, and Security Initiative is needed.

Dr. Austin raised the problem presented by space debris and asked whether progress is being made internationally to make space safe for everyone. Dr. Holdren responded that the Administration has continuous discussions with other

spacefaring countries and is in bilateral discussions with the most important partners. Talks with the Chinese have had success and they continue to be in touch with the Russians about the same question. He recognized that this is a larger problem than has been acknowledged and that a larger, more coordinated effort is needed. Mr. Bolden noted that he had spoken recently at an international forum attended by emerging spacefaring nations and was pleased to see that they understand the risks from space debris. The challenge at NASA is to continue to work with the Congressional overseers to be able to work more in an expanded collaboration with international partners who affect that environment.

Dr. McComas noted that there are over 100 missions in the Science Mission Directorate (SMD) and that these missions account for over 10 percent of all science worldwide. Three quarters of that impact comes from extended missions, which cost very little compared to the initial investments. He asked for the Administration's perspective on getting science from those huge investments that have already been made. Dr. Holdren responded that the flagship commitment by the Administration has been the decision to extend the ISS to 2024 and beyond. That is the single biggest investment that has been made in space and it is the Administration's position that it would be a tragedy if the full scientific and technical value of the ISS was not extracted from it. He acknowledged that this is a perennial problem and noted that Program Officers generally prefer to start new programs rather than manage existing, successful programs. There is a need to get past that somehow, in part, by recognizing continuing achievements from the flow of data that come from those continuing missions. This can be accomplished by telling the stories about how important insights have continued to emerge from projects that have existed for awhile. Mr. Bolden remarked that this is a favorite topic for him and that it is a situation where you cannot have it both ways. A major focus of NASA's Senior Review panels is looking at ongoing missions and determining which ones are going to be continued. NASA always budgets to the planned life-time for a mission, knowing that it will typically last 3 to 5 times longer than it was designed to last. That is not smart. He understands that this strikes a "bad chord" with the science community because he is being asked to budget more money than he now budgets in order to get projects accepted. If he budgets what it is really going to take, the project will be too expensive and will not be accepted. The HST was raised as an example of the problem; if it had been stopped at the end of its planned lifetime, where would we be? It is an incredibly viable asset, but it eats up resources. There is a need to decide how to prioritize creating opportunities for young, emerging scientists and investigators. Joining a program that is underway does not give them an opportunity to be on the ground floor in a way that will make them a Nobel Prize winner as opposed to doing data analysis and data collection with old instruments. He suggested that the scientific community should wrestle with its own problem and not depend on somebody finding more money that will enable them to dodge the question of how long is too long for a particular program.

Ms. Blakey noted that opportunity and challenge in this generation on which the President has shown leadership involves unmanned aircraft systems (UAS). There are two major challenges that need White House leadership. First, the Nation is foundering on bringing UAS into the national airspace. She was delighted to see that NASA is working on air-traffic control for unmanned aircraft; however, there does not seem to be a plan on a near-term basis to bring unmanned aircraft into the national airspace despite the many benefits, for example: public safety, search and rescue, and border monitoring. The second issue involves the Missile Technology Control Regime (MTCR), which was created to curb the spread of unmanned aerial vehicles (UAV) for all weapons of mass destruction and which prevents the U.S. leadership in this area from being exported at any level. The U.S. is about to be eclipsed in this technology by other nations. She asked for the Administration's view on this subject. Dr. Holdren responded that the question of air traffic management for UAVs has not been neglected. He has attended several meetings on this subject with the Department of Transportation (DOT), the Federal Aviation Administration (FAA), and at the White House. They are aware of the challenges and the opportunities and agree about the potential. There are privacy issues to be considered. They also are looking at export controls more broadly, because many existing restrictions seem to be overly restrictive in the current environment. He expects to see progress in this area. Ms. Blakey expressed concern that the FAA is losing control over UAVs due to their proliferation. Dr. Holdren agreed to take that concern back to the White House.

Mr. Young asked whether the U.S. exploration strategy was more of a passion and a dream than a strategy because a strategy requires resources to be committed in a matter that ensures it can be executed. Mr. Bolden responded that there has never been a time when a U.S. exploration strategy has been adequately resourced. That is because a strategy requires one to look at multiple budget horizons. A Mars strategy would require an Administration to be able to make a commitment for multiple administrations, and they cannot do that. In order to determine the life-cycle costs for the SLS, one would need to ask when the end-of-life is for SLS. There are many estimates for how

much it will cost to go to Mars. There is a need to get to the point where a monetary value can be assigned to years expected for the program. NASA conducts Strategic Implementation Planning Sessions where long-range, 30-year plans are developed. There is no current, valid Mars strategy that would be commonly accepted; however, NASA is working on a plan that identifies the milestones that are needed to get there. Moreover, he is prohibited from discussing such a long-term strategy with potential international partners. There cannot be a valid strategy if one is compelled to discount potential international partners that will be available in the future.

Dr. Squyres raised a question concerning the human exploration of asteroids. He noted that President Obama, in his April 15, 2010 national space policy speech several years ago at KSC, had spoken about developing new spacecraft that could go further into space than ever before, beyond the Earth-Moon system, and set humans on asteroids. Now, NASA's next step in human exploration is to send astronauts to rendezvous with a very small asteroid that has been redirected to the Earth-Moon system and put into orbit around the Moon. With respect to the goal outlined in the President's speech, will NASA's next step satisfy that goal, or will it still be necessary to visit an asteroid that has not been relocated? Dr. Holdren responded that the current version of the NASA plan is consistent with the President's vision. The idea is to get three benefits: (1) make technological advances that are potentially relevant to commercial exploration of the asteroid and will advance the ability to address the threats that near-Earth objects pose to Earth; (2) to do that using technologies that are already developed or in development; and (3) reestablish a U.S. presence not only near the Moon, but beyond the Moon as a stepping stone towards Mars. How that will be accomplished is still evolving. It is an incredibly valuable mission in terms of the purposes it serves, largely using technologies and components being developed with current budgets. Dr. Holdren acknowledged that some people want to return to the lunar surface; however, he does not believe that spending \$60-\$80 B for that purpose is the best way to use that money in the current environment. People are not realistic about the cost. Getting people to become very realistic about the cost is very difficult, not least because of the way we fund the things year by year. No Congress or Administration feels bound by its predecessor. How to get past that is a challenge for everyone. Mr. Bolden noted that at his 2009 Senate confirmation hearing as NASA Administrator, he made three promises: (1) he would not bring something forward that does not pass the common sense test and is not feasible; (2) he would not bring something forward that is not believed to be sustainable; and (3) he would not bring something forward that is not affordable. He believes that NASA is going to have to accept a lot more risk on the asteroid mission than usual, and that it may be unattainable. NASA is going to an asteroid for the same reason that NASA goes to planets – in order to understand more about Earth. Scientists believe that asteroids are the basic building block in what created planet Earth. There are important scientific objectives that can be accomplished if samples from a small asteroid can be brought back to Earth.

Dr. Squyres thanked Dr. Holdren and Mr. Bolden for taking the time to meet with the Council and answer the Council members' questions.

NASA Human Spaceflight Update: Asteroid Initiative Update

Dr. Squyres introduced Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Mission Directorate, NASA HQ. Mr. Gerstenmaier discussed NASA's Exploration Strategy. The reasons for human space exploration were reviewed. It expands human knowledge and experience, ignites imaginations, leads to science and technical advances, creates a vision of a better future for the next generations, garners national prestige, and unites nations around a common goal. He described how robots and humans both advance exploration. Robots help explore distant and hazardous environments. Human explorers provide greater speed, intuitive ease, and efficiency than robots. Mr. Gerstenmaier described three zones that make up NASA's building blocks for going eventually to Mars. The "Earth Reliant" zone is used for missions that last from 6 to 12 months and allow the crew to return to Earth within hours. This is LEO and involves mastering fundamentals aboard the ISS. The "Proving Ground" zone is used for missions that last one to 12 months and allows the crew to return to Earth within several days. These missions involve traveling beyond LEO with the SLS and the Orion crew capsule. The "Earth Independent" zone is used for missions that last 2 to 3 years and requires months before the crew can return to Earth. Planetary independence is established in this zone by exploring Mars, its moons, and other deep space destinations.

A chart showing the Capability Driven Framework was presented. These are incremental steps to steadily build, test, refine, and qualify capabilities that lead to affordable flight elements and a deep space capability. Mars is shown on the chart as the ultimate human destination in the next decades. Mr. Gerstenmaier discussed the strategic principles for exploration implementation. He presented a chart showing six key strategic principles for a sustainable program:

1. Executable with current *budget with modest increases*.
2. Application of *high Technology Readiness Level (TRL)* technologies for near term, while focusing research on technologies to address challenges of future missions
3. *Near-term mission* opportunities with a defined cadence of compelling missions providing for an incremental buildup of capabilities for more complex missions over time
4. Opportunities for *U.S. Commercial Business* to further enhance the experience and business base learned from the ISS logistics and crew market
5. *Multi-use, evolvable* Space Infrastructure
6. Significant *International and Commercial participation*, leveraging current International Space Station partnerships

Mr. Gerstenmaier acknowledged that the one percent budget increase planned for NASA is more modest than what will be needed and that he does not expect to see the requisite modest increase in the future. He explained that the techniques needed for the ARM must feed forward to the Mars mission. For example, the robotic spacecraft for the ARM will be used for Mars cargo missions. In response to a question from Dr. Squyres, Mr. Gerstenmaier agreed that the costs for requirements associated with sending cargo to Mars will be levied onto the ARM. In response to a question from Mr. Young, Mr. Gerstenmaier acknowledged that the first strategic principle will preclude landing humans on Mars by the mid-2030's. Mr. Young observed that the NASA strategy is not in balance with the available resources and that the Nation is on shaky grounds if it intends to land humans on Mars by 2035. Dr. Austin requested strategic principles that fit within the current budget. She counseled that NASA should explain what cannot be obtained within the budget. Dr. Squyres recommended that it be stated clearly that NASA's goals for human space flight cannot be achieved with a flat budget. Mr. Gerstenmaier noted that no other country is building an Orion capsule to take crew into deep space or building a deep space rocket like the SLS. Russia and China now believe that they need to develop a deep space rocket. He feels it would be advisable, therefore, to leverage off international participation.

A chart showing the Global Exploration Roadmap was discussed. Mr. Gerstenmaier explained that it is not a NASA plan; it is a roadmap laid out by NASA, together with the international partners. He noted that the international partners are very interested in conducting lunar activities. NASA can assist them if they wanted to produce a lunar lander. NASA will focus on the Mars problem and allow the partners to focus on the Moon problem. He added that the Moon would allow more experience in low gravity than can be obtained on the ISS.

Mr. Gerstenmaier explained that the ISS is the platform to understand and develop countermeasures for human health and performance risks. Dr. McComas asked what was being done to provide shielding from radiation. Mr. Gerstenmaier replied that radiation shielding is going to be very difficult. They are looking at using magnetic shielding and drugs. In addition, the National Institute of Medicine is reviewing the ethical standards for radiation exposure. He explained that the next step beyond the ISS will be a crew-tended habitat in cis-lunar space. It builds off the ARM and the ISS and allows for Mars operational strategies to be developed. Dr. Squyres asked how the module for the habitat would be developed. Mr. Gerstenmaier explained that the commercial sector and international partners have expressed an interest in developing the module. He described how Commercial Crew and Crew Transportation are freeing NASA to explore beyond LEO. NASA is now acquiring ISS cargo services commercially. Slides were presented showing the SpaceX C1 launch, the SpaceX C2+ launch, the Orbital A-1 launch, the Orbital OB-D1 launch, the SpaceX Dragon capture, and the Orbital Cygnus capture. A chart showing the Commercial Crew partners: Boeing, SpaceX, and Sierra Nevada, was presented. A chart was presented showing the Commercial Crew Program from 2010 through 2017, covering Commercial Crew Development (CCDev), Commercial Crew Development Round Two (CCDev2), Commercial Crew Integrated Capability (CCiCap), and Commercial Crew transportation Capability, phases one (CPC) and two (CCtCap). He reported that the intention is to select a contractor for Commercial Crew by August or September 2014.

Mr. Gerstenmaier briefed the Council on the status of Exploration Flight Test One (EFT-1), Exploration Mission One (EM-1), the Orion Spacecraft, the SLS, and Ground Systems Development and Operations (GSDO). EFT-1 will lift off on a Delta IV Heavy Rocket, make two orbits around the Earth and re-enter at 80 percent of the speed that would be experienced in a lunar return mission. A primary intent is to test the heat shield. EM-1 will be outbound for 9 days, obtain a distant retrograde orbit with help from a lunar gravity assist, stay 5 days in that orbit, then return to Earth in approximately 11 days. It will rely on four RS-25 engines remaining from the Space Shuttle Program. He

noted that the Orion is the first spacecraft in history with the capability to take humans to multiple destinations in deep space. GSDO is modernizing the KSC spaceport with the capabilities to launch spacecraft built and designed by both NASA and private industry.

Mr. Gerstenmaier briefed the Council on the ARM. It has three components: (1) asteroid identification; (2) an asteroid redirect robotic mission using high-power SEP to redirect an asteroid to lunar distant retrograde orbit; and (3) an asteroid redirect crewed mission, which will be an Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid. He explained ARM objectives. It will provide systems and operational experience needed for human exploration of Mars. It will demonstrate advanced SEP. It will enhance detection, tracking, and characterization of near-Earth asteroids (NEAs), enabling an overall strategy to defend Earth. It will demonstrate basic planetary defense techniques that will inform impact, threat-mitigation strategies. It will benefit scientific and partnership interests by expanding knowledge about small celestial bodies and enabling the mining of asteroid resources. He explained that the ARM builds on investments already being made by NASA. There are two options for the asteroid redirect robotic mission. Option A is to rendezvous with an NEA less than 10 meters in diameter. Option B is to rendezvous with a larger NEA that is approximately 100 meters in diameter and to retrieve a 2 to 3 meter diameter boulder from that asteroid. A chart was presented showing how the ARM provides capabilities for deep space and Mars missions. Mr. Gerstenmaier noted that NASA's focus on Mars does not preclude NASA from lunar activities. The Moon, however, is not viewed as necessary for the Mars missions. A chart was presented on the Solar System Exploration Research and Virtual Institute (SSERVI). SSERVI provides scientific, technical, and mission-defining analysis for relevant NASA programs, planning, and space missions. He described the Mars 2020 mission. It will be a collaboration among the Science Mission Directorate (SMD), the Human Exploration and Operations Mission Directorate (HEOMD), and Space Technology Mission Directorate (STMD). The Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) program was described. Its purpose is to accelerate private sector lunar landing capabilities with NASA expertise using public-private partnerships. A chart on evolutionary capabilities was presented. The chart is a matrix showing evolutionary capabilities in transportation, working in space, and staying healthy across the Earth reliant zone, the proving ground zone, and the Earth independent zone. Mr. Gerstenmaier noted that the chart is a work in progress, and he requested the Council's assistance in developing it. A chart on an evolvable Mars campaign was presented. The chart shows where decisions need to be made in the future. Mr. Gerstenmaier concluded his presentation by reviewing a chart on the evaluation criteria for pathways to human space exploration.

Mr. Gerstenmaier was asked about the SLS launch cadence. He responded that SLS is expected to fly about once a year with a flat budget. Dr. Squyres encouraged Mr. Gerstenmaier to complete a trade study on ARM, converge on a course of action, and then carry out a completely independent, non-advocate cost estimate. Mr. Hale asked whether there is a back-up plan. Mr. Gerstenmaier responded that they have tried to retire major risks and that right now everything is on the critical path. Due to the budget environment, he cannot protect every option and at some point he will need to choose one path. Mr. Young noted that while his personal passion is humans on Mars, there is a chance that NASA's exploration program is beyond reasonable reach and needs a different focus. Mr. Gerstenmaier responded that Mars is what needs to be done because there is a need to move human presence into the solar system. Significant and measured progress towards that goal can and should be made. Without modest budget increases, however, it cannot be accomplished by a date certain. Dr. Squyres commented that he always asserts that NASA's projects should be implemented by optimists and costed by pessimists.

Dr. Squyres thanked Mr. Gerstenmaier for his presentation.

President's FY 2015 Budget Request for NASA

Dr. Squyres introduced Dr. Elizabeth (Beth) Robinson, Chief Financial Officer, NASA HQ. Dr. Robinson presented charts on the highlights of the President's FY 2015 Budget Request for NASA. As summarized in those charts, the budget:

- Provides the necessary resources to advance the Nation's bipartisan space exploration plan and ensure that the United States remains the world's leader in space exploration and scientific discovery for years to come;
- Aligns NASA's activities to send humans to an asteroid by 2025 and Mars in the 2030s;

- Supports the Administration's commitment that NASA be a catalyst for the growth of a vibrant American commercial space industry;
- Builds on U.S. preeminence in science and technology, improves life on Earth and protects our home planet, while creating jobs and strengthening the American economy;
- Extends the life of the International Space Station (ISS) until at least 2024, which is essential to achieving the goals of sending humans to deep space destinations and returning benefits to humanity through research and technology development;
- Acquires commercial cargo supply missions to the ISS with launches from our shores, and further advances NASA's initiative to return human spaceflight launches to the United States by 2017;
- Enables partnerships with American industry to develop new ways to reach space, creating jobs and enabling NASA to focus on new technologies that benefit all of our missions;
- Funds the SLS and Orion space crew vehicle to take astronauts farther into the Solar System than we have ever gone before;
- Invests in transformative space technologies, such as high powered SEP, advanced robotics, high speed communications and precise navigation that enable future NASA missions, and increase the Nation's capabilities in space;
- Advances NASA's first-ever mission to identify, capture and redirect an asteroid, which represents an unprecedented technological feat -- raising the bar for human exploration and discovery, while helping protect our home planet and bringing us closer to a human mission to one of these mysterious objects and building deep space capabilities needed for future missions to Mars;
- Continues to build on our Nation's record of breathtaking and compelling scientific discoveries and achievements in space, with science missions that will reach far into our Solar System, reveal unknown aspects of the Universe and provide critical knowledge about our home planet;
- Continues NASA's global leadership in planetary exploration, with funding for missions to Mars, a potential mission to Europa, missions already heading toward destinations such as Jupiter and Pluto, and missions operating throughout the solar system;
- Sustains NASA's vital role in understanding the Earth's systems and climate and the dynamics between our planet and the Sun -- by the end of FY 2015, NASA will have launched an unprecedented five Earth science missions to find answers to critical challenges facing our planet today and in the future, including climate change, sea level rise, freshwater resources and extreme weather events;
- Makes steady progress toward our next Great Observatory as we develop and conduct critical tests on the James Webb Space Telescope -- planned for launch in 2018 -- that will again revolutionize our understanding of the universe;
- Aligns Aeronautics research to focus on newly defined strategic thrust areas that address a growing demand for mobility, severe challenges to sustainability of energy and the environment, and technology advances in information, communications, and automation technologies;
- Continues to develop methods and technologies to support implementation of Next Gen;
- Creates new jobs right here on Earth -- especially for the next generation of American scientists and engineers -- by supporting cutting edge aeronautics and space technology innovations, education, research and development that will help fuel the Nation's economy for years to come; and

- Builds on efforts proposed in the 2014 Science, Technology, Engineering and Mathematics (STEM) Education budget and continues to reduce fragmentation, supporting a more cohesive infrastructure for delivering STEM education and leveraging existing resources to improve the reach of Agency assets.

Dr. Robinson presented a chart comparing NASA's \$17.6465 B enacted budget for FY 2014 to the \$17.460.6 B President's Budget Request for FY 2015. The net decrease is \$185.9 M. She noted that NASA has accepted the challenge to manage to a modest inflation-adjusted budget. The budget continues NASA's efforts to improve operational efficiency, and maintains reduced spending for service contracting, travel, supplies and materials, printing and reproduction, and IT services. Dr. Robinson agreed to accommodate Gen. Lyles suggestions that the line item for Aeronautics, in the future, be shown first in the chart in accordance with the letter "A" position in the alphabet, and that there be additional delineation shown in the chart for that line item. She described the Opportunity, Growth, and Security Initiative (OGSI). This is funding provided to partially make up for sequestration cuts that were not fully replaced by the Bipartisan Budget Act of 2013 (BBA). The OGSI for all Federal agencies is \$56 B and NASA's share is \$885.5 M. A chart showing details for how NASA's OGSI funds are allocated was presented. The largest share is \$250 M for the CCP, followed by \$100 M for SLS and Orion and \$93.7 M for the NASA Langley Research Center (LaRC) Measurement Sciences Lab. A chart showing planned NASA mission launches from FY 2014 through FY 2020 was shown. Dr. Robinson presented charts showing five-year budgets for Earth Science, Planetary Science, Astrophysics, JWST, Heliophysics, Aeronautics, Space Technology, Exploration Systems Development, Commercial Spaceflight, Exploration Research and Development, the ISS, Space and Flight Support, Education, and Cross-Agency Support and Construction. With respect to the Astrophysics budget, it was noted that the Stratospheric Observatory For Infrared Astronomy (SOFIA) would be placed into storage unless the U.S. share was undertaken by international partners. In response to a question from Dr. Squyres, Dr. McComas agreed to have his committee determine how the decision was made on SOIA.

A chart on Joint Agency Satellite (JAS) Programs was presented. The Joint Agency Satellite Division (JASD) within the SMD manages NASA's fully reimbursable satellite and instrument development program, which currently includes NOAA-funded missions. JASD offers other Federal agencies a single interface for planning, developing, and managing their satellite projects. Dr. McComas asked who owns the risk on the programs JASD manages. Dr. Robinson responded that NOAA owns the risks, but only in theory because NOAA is a small \$2-4 B agency. Several items have shifted over to the NASA portfolio over time; however, NOAA has the risk on the big items. Dr. Robinson discussed a chart on the Asteroid Mission Initiative. The ARM will enable human rendezvous with an asteroid before 2025 and prepare for missions to Mars. NASA is committed to pursuing an affordable and feasible mission. The Budget provides \$133 M for early development efforts on the asteroid mission. A chart showing additional funding for the asteroid initiative was reviewed.

Dr. Squyres thanked Dr. Robinson for her presentation.

Council Discussion

Dr. Austin expressed a need for further clarity in the NAC 2014 Work Plan item that addresses acquisition reform. Gen. Lyles concurred. Dr. Squyres assigned this item to the Institutional Committee under Ms. Schmoll's leadership, along with the item on overhauling NASA's IT Governance Structure. He asked Ms. Schmoll to prepare a note requesting clarification on the acquisition reform item for him to send to the Administrator. Dr. Squyres assigned the Work Plan item on Capability Driven Framework for Future Human Exploration to Mr. Bowersox and his HEO Committee. The Work Plan item on Human and Robotic Mission Cooperation was jointly assigned to the Science Committee and the Technology and Innovation (T&I) Committee. Dr. Squyres noted that joint committee meetings would be readily accommodated at the next NAC meeting in July because all the committees would be meeting at the same location that week.

Dr. Austin suggested that Council assistance could help the Administrator show what the current funding level would achieve towards the Exploration Strategy and, thereby, keep people from feeling the budget is disingenuous. Dr. Kennel agreed that the budget for this item lacks credibility. Mr. Young asserted that it is not close. He observed that it does not come across as a strategy if the resources are inadequate and that the "disconnect" between the dream and reality is alarming. Dr. McComas suggested that the disconnect be quantified. Dr. Squyres advised that it is important to understand the circumstances in which stretching the schedule out would cause the strategy to fall apart, either because the chance for the mission to actually take place is so slight that it is not worth pursuing, or

because the flight cadence becomes alarmingly slow. Gen. Lyles noted that NASA needs an additional \$3 B for the strategy, according to the Augustine report, and has not received anything close to that amount. Dr. Kennel suggested that the strategy is more like a commitment than a program since it is not known how to accomplish it. He added that the biggest problem would be not having interesting things happen along the way. Dr. Squyres questioned whether a flexible path concept for a big goal like going to Mars was compatible with the current budget environment. Mr. Hale remarked that it could work if a big program like the ISS ended and NASA could retain the funds.

Dr. Squyres observed that NASA has two ongoing human spaceflight programs: (1) SLS and Orion to explore deep space, and (2) the ISS and Commercial Space. He questioned whether it is feasible to conduct both at the same time. Ms. Schmoll advised that it was not feasible. Dr. Kennel observed that it has become a very tense situation. In response to a query from Dr. Squyres, Mr. Hale advised that the SLS flight rate is not sustainable, is too slow to keep necessary support together, and that it is questionable whether it should be pursued. Dr. Ballhaus counseled that when schedule is used as a relief valve, the point is reached where everything breaks. Dr. Squyres asked the Council to focus on this problem. He explained that NASA is being called upon to do too much with it too little, and that the Council is charged with providing the Administrator with advice that he can use. Advising him that he is being asked to do too much with too little will not be helpful. Mr. Young explained that it is dangerous when costs become more important than mission success or safety. He wants NASA to continue to be the “gold standard” for mission success. Dr. Squyres concurred and reemphasized that doing something too infrequently compromises human safety and mission success. Gen. Lyles advised that: (1) the mission should be affordable, sustainable, and critical; (2) NASA should “go as it can afford to pay;” (3) the program has to be credible and sustainable to Congress and the public; and (4) it is important to have “demonstrable successes” to show the public that NASA is on the right path.

Dr. Kennel concurred with Dr. Austin’s concerns about space debris and asserted that actionable advice on it could be given to the Administrator. He reported that space debris has been studied by the National Research Council (NRC) and that it is possible to forecast when it is going to become a critical international problem. In 20 years it will be a serious impediment to LEO. He noted that most work on space debris is being conducted at a low level at NASA Johnson Space Center (JSC). He recommended that NASA bring international attention to the situation by issuing periodic reports on when the problem will become critical. Dr. Austin supported Dr. Kennel’s recommendation. Dr. Squyres requested Dr. Austin and Dr. Kennel to prepare a joint recommendation for the Council to consider. Mr. Hale asserted that cleaning up orbital debris is much more difficult than going to Mars. Ms. Blakey suggested having a NASA briefing on the subject before submitting the recommendation to the Council for formal action. Dr. Squyres agreed that after the draft recommendation is presented to the Council, the recommendation should be tabled until the next Council meeting and considered by a committee in the interim. Gen. Lyles expressed concern that NASA no longer is putting an emphasis into hypersonics research.

Aeronautics Committee Report

Dr. Squyres introduced Ms. Marion Blakey, Chair, Aeronautics Committee. Ms. Blakey reviewed the Committee membership and the Committee’s 2014 work plan. A chart showing the FY 2015 President’s Budget Request for Aeronautics was discussed. Ms. Blakey noted that the budget is \$14 M below the 2014 level and that the budget will not reach the 2014 level again until 2018. She described a recent reorganization within the NASA Aeronautics Research Mission Directorate (ARMD). ARMD has three goals: (1) pursue innovative solutions that are aligned to strategic thrusts; (2) incentivize multi-disciplinary “convergent” research; and (3) enable greater workforce and institutional agility and flexibility. There are three mission programs: Air Operations and Safety Program, Advanced Air Vehicle Programs, and Integrated Aviation Systems Program. There is also a seedling program: Transformative Aeronautics Concepts Program. ARMD’s research is being aligned under six strategic research and technology thrusts:

- Safe, efficient growth in operations
- Innovation in commercial supersonic aircraft
- Ultra-efficient commercial vehicles
- Transition to low-carbon propulsion
- Real-time system-wide safety assurance

- A short autonomy for aviation transformation

A chart explaining the Transformative Aeronautics Concept Program was discussed. The Program solicits and encourages revolutionary concepts, creates the environment for researchers to become immersed in experimenting with new ideas, performs ground and small-scale flight tests, and drives rapid turnover for new concepts. Two sample "big questions" are: (1) can UASs be integrated into urban environments, and (2) can a small airplane be made as easy to fly as a car is to drive and as safe as commercial airline operations? A chart on Foundational Technologies & Strategic Thrusts was presented. It notes that foundational research enables multiple thrusts. Ms. Blakey observed that the reorganization is a work in progress and that foundational research needs to play a strong role in the new seedling program, but must also maintain a strong connection to the other programs.

Ms. Blakey presented a proposed Committee finding for ARMD to maintain its commitment to foundational research and to continue its investment in Vertical Lift research. In response to a query from Dr. Squyres, Mr. Blakey confirmed that this finding was intended to go from the Aeronautics Committee to the Associate Administrator for ARMD. The Council approved the following finding:

The Aeronautics Committee endorses the approach that NASA ARMD is taking to restructure their organization to not only continue research on relevant and critical aviation problems, but also to renew emphasis on activities focused on high-risk, forward thinking ideas. However, the Committee is concerned critical areas of Aeronautics research may get "lost in the shuffle" as the restructure is implemented. The Committee finds that it is imperative for ARMD to maintain its commitment to both that foundational research which has always been at the core of the NASA Aeronautics mission and to continue its investment in Vertical Lift research and technology to enable U.S. leadership gains in this critical area of aeronautics.

Ms. Blakey reported that the Joint Planning and Development Office (JPDO) has been abolished through the appropriations process. She presented a proposed Finding for NASA to discuss with the FAA how to continue the JPDO's strategic aspects. Dr. Squyres observed that this is a "recommendation disguised as a finding." Ms. Blakey concurred. Gen. Lyles advised that industry strongly supports the principle encompassed in the finding. The Council approved the Finding as follows:

The Council would like to recognize the value of the work that NASA has supported through the Joint Planning and Development Office (JPDO). Funding for the JPDO was eliminated in the current appropriations and activities pursued by that organization are currently being integrated back into existing FAA organizations. The Council encourages NASA to discuss with the FAA how best to continue the relevant strategic and forward looking aspects that were part of the JPDO.

Ms. Blakey presented a proposed Committee Finding to endorse NASA/DARPA collaboration. Dr. Squyres noted that this appeared to be a Council recommendation for the Administrator. Ms. Blakey concurred. In response to a question from Dr. McComas, Mr. Blakey explained that DARPA, rather than DOD, is mentioned because DARPA is more willing to tackle low technology readiness level (TRL) activity. At Mr. Hale's suggestion, rocket propulsion was included in the recommendation. The Council approved the Recommendation as follows:

The Council endorses NASA/DARPA collaboration on programs of mutual interest and advises that NASA engage DARPA leadership to identify and explore opportunities where commercial technology can benefit future military missions and/or where military technologies can benefit civil and commercial applications. Current technology areas of mutual interest include (but are not limited to) hypersonic flight, autonomous/unmanned air systems, vertical lift technology, collaborative vehicle operations for enhanced airspace/mission management, related data analysis tools, and rocket propulsion development.

Ms. Blakey discussed UAS Traffic Management (UTM). The goal for UTM is to enable safe and efficient low-altitude airspace and UAS operations. Ms. Blakey observed that little attention has been given to safe operation under the 2000 foot airspace and that small aircraft have proliferated greatly. A burgeoning commercial use is expected in this area. No infrastructure to safely support these operations is available. It was noted that Air-Traffic Management (ATM) began after a mid-air collision over the Grand Canyon in 1956. Ms. Blakey presented a proposed Committee Recommendation for NASA to be proactively engaged in reducing barriers to realizing UTM. The Recommendation is as follows:

Many civilian applications of Unmanned Aerial Systems (UAS) have been imaging ranging from remote to congested urban areas, including good delivery, infrastructure surveillance, agricultural support, and medical services delivery. However, key infrastructure to enable and safely manage widespread use of low-altitude (up to 2000 feet in Class G) airspace and UAS operations therein does not exist. NASA is exploring concepts and technology development for a prototype UTM system. UTM will support safe and efficient UAS operations for the delivery of goods and services.

A number of partners have expressed an interest in working with NASA in exploring the research, development, prototyping, testing and possible implementation of the UTM system. Public/private/academia relationships are expected (and necessary) to help define and develop a UTM system. The Committee recommends that the NASA Administrator and all NASA organizations involved in the development and sustainment of agreements and partnerships be proactively engaged in reducing implementation barriers and provide any necessary tools to enable the innovative partnerships that will be required for the realization of UTM

In response to a question from Dr. McComas, Ms. Blakey explained that the FAA is having difficulty keeping all UAS operators under control and there is a concern that the field could develop like the Internet where DOD did not maintain control. At Dr. Squyres' request, Ms. Blakey agreed to restate the recommendation into the Council's standard format and to re-present it for Council action on the following day. She agreed to do so. Ms. Blakey concluded her presentation by describing ARMD's engagement with universities across the Nation.

Dr. Squyres thanked Ms. Blakey for her presentation.

Science Committee Report

Dr. Squyres introduced Dr. David McComas, Chair, Science Committee. Dr. McComas reviewed the Committee membership. He noted that the Committee's recent activity has been limited. There are five science subcommittees and only two have met since the last NAC meeting. The Committee met by teleconference; however, substantive interaction was limited due to the telecon structure.

Recent science results were reviewed. The Interstellar Boundary Explorer (IBEX) Mission is an Explorer-class satellite designed to image the heliosphere's edge around the Solar System. IBEX is providing new insight on the magnetic system beyond the solar wind, which Dr. McComas explained expands at over one million miles per hour. The NASA Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) is a new space weather tool that provides real-time assessments about radiation risks from galactic cosmic rays and solar energetic particles to commercial air crews and passengers. The Ground-to-Rocket Electrodynamics-Electrons Correlative Experiment (GREECE) mission is a sounding rocket that was launched into an aurora over Alaska to study classic curls that form in the aurora. The Unmanned Air Vehicle Synthetic Aperture Radar (UAVSAR) is a remote sensing radar instrument and is being used to help understand California's aqueduct. The Moderate-resolution Imaging Spectroradiometer (MODIS) is being used to monitor the soybean crop in Argentina and Brazil. It is helping to stabilize markets and lower food prices by improving crop assessments. The Hubble Space Telescope (HST) has been used to discover 125-mile high water plumes on Jupiter's moon Europa, suggesting cracking on the surface due to stress. A recent Cassini fly-by has detected water on Saturn's moon Enceladus. The HST has photographed the never-before-seen break-up of an asteroid, Asteroid P/2013. Lunar pits have been observed on the moon. These are subsurface voids or caves that provide shelter from radiation and micro-meteorites, and a constant -20 degrees C temperature. The Nuclear Spectroscopic Telescope Array (NuSTAR) is the first telescope able to image radioactive supernova remnants and is helping to understand how stars detonate. A long-exposure HST image of Frontier Field Abell 2744 was presented showing light emitted from one of the youngest galaxies in the universe 650 million years after the Big Bang. A chart showing the sizes of known exoplanets was presented.

Dr. McComas discussed the NASA Science Mission Directorate's (SMD's) programmatic status. A chart was presented showing SMD has 92 missions represented by 122 spacecraft in formulation, implementation, primary operation, or extended operation. Since August 2011, SMD has launched 11 missions for which it had made development cost commitments. Two missions overran significantly. The other nine missions underran their original cost estimates, in the aggregate, by about 6 percent. The outlook for the future suggests similar outstanding performance. It was noted that good cost and schedule performance contributes to stability in SMD's programs. Dr.

Squyres advised that this is very important. Dr. McComas described a chart showing Agency and SMD budget trends. The budget fraction going to SMD has remained relatively constant over time. A chart showing the FY 2015 SMD Budget Request was presented. Dr. McComas discussed a chart showing SMD science as a percentage of worldwide science. The chart indicates that the total SMD science mission return exceeds 14 percent of worldwide science, and that the return from extended SMD science missions exceeds 10 percent. Dr. McComas noted that the cost to operate extended missions is only a tiny fraction of the SMD budget and is a small incremental expenditure for a great deal of science.

A slide was presented on the Heliophysics System Observatory. This is a coordinated and complementary spacecraft fleet used to understand the Sun and its interactions with Earth and the Solar System. NASA has a \$5.5 B total investment in heliophysics space assets (excluding launch costs), which require a \$68 M annual operating budget. NASA's Solar Probe Plus (SPP) mission has passed the Key Decision Point-C (KDP-C) Confirmation Review, which is the Agency-level approval for a project to transition from formulation to implementation. It will fly into the Sun's outer atmosphere and gather data on the processes that heat the corona and accelerate the solar wind, solving two fundamental mysteries that have been top-priority science goals for many decades. Five new Earth Science missions were launched in 2014. Dr. McComas described the recently repaired ISS SERVIR Environmental Research and Visualization System (ISERV), which automatically takes images of Earth through a small telescope with an off-the-shelf digital camera mounted in the ISS. The Global Precipitation Measurement (GPM) Core Observatory is a joint Earth-observing mission between NASA and the Japan Aerospace Exploration Agency (JAXA). It launched in February aboard a Japanese H-IIA rocket from Tanegashima Space Center in southern Japan and will measure precipitation.

Dr. McComas discussed the Mars 2020 mission. It is an exciting new opportunity to go back to Mars. STMD and HEOMD are sponsoring Mars 2020 investigations to address technology gaps. The recent discovery of water vapor plumes on Europa has led to NASA issuing a Request for Information (RFI) and a planned Announcement of Opportunity (AO) for science instrument proposals. The mission cost will be over \$2 B and likely will be beyond available budget funding. Mr. Young asked whether there is a requirement for responses to be consistent with the NRC Decadal Survey. Dr. McComas replied that responses should be driven by the NRC Decadal Survey. Mr. Young advised that a Europa mission that satisfies the Decadal Survey would cost almost \$1 B and would be impossible to fund. Dr. Squyres asked whether there is an intention to subject potentially promising RFI responses to an independent cost and technical assessment to validate the costs. Dr. McComas responded that the process is still being developed and that the Committee's focus had been on how proposers' intellectual property could be protected. Mr. Young concurred with Dr. Squyres concern and noted that the probability that some people will say they can do it is 100 percent. Mr. Bowersox commented that the challenge being raised is important and that modifications to conventional program analysis tools are available to help produce better results. Dr. Squyres stated that it is imperative that any potentially promising responses to the RFI be subjected to a rigorous cost analysis. Dr. McComas briefed the Council on the status of the JWST. Flight optics for JWST have been delivered and all mirrors are in storage at GSFC. He discussed the Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets (WFIRST/AFTA). It was noted that the FY 2015 budget request supports pre-formulation of WFIRST/AFTA and that a recent NRC study offers a positive view of the project, although there are concerns about technology and costs.

Dr. McComas submitted a proposed Committee finding to the SMD AA on the SOFIA funding process. He noted that the Committee only wanted to comment on the process and did not agree or disagree with the decision. Dr. Kennel reported that his NRC committee had the same position. Dr. Austin noted that there have been interim reviews for cancellation. Mr. Young noted that SOFIA had been canceled once before. Dr. Ballhaus advised that the German Aerospace Center (DLR) did not feel that it had been appropriately consulted. Mr. Young suggested that the defunding may have been handled properly, depending upon the circumstances. Dr. McComas elected to withdraw the proposal and to take it back to the NAC Science Committee for further consideration.

Dr. Squyres thanked Dr. McComas for his presentation.

Public Input

Dr. Squyres invited members of the public to make comments or address the Council. A gentleman identified himself as Charles Divine and stated that he was one of the leaders of the Metropolitan Washington Mensa

organization. He stated that he also served in the past on a Governor's Workforce Investment Board. Mr. Devine reported that both groups have an interest in the Science, Technology, Education and Math Education problem. He noted that some people are adding the letter "A" for "arts" and calling it the STEAM problem. They are concerned that young people are entering STEM fields after college, but then are dropping out of these fields at a rate of two-thirds or more. The reasons some are dropping out are: (1) a very poor work/life balance; and (2) very poor managers that they run into when they get into these fields. In this regard, the February 2014 Mensa bulletin has an article entitled "Zombie Nation" about people who are so sleep-deprived that they are making a lot of mistakes. The article discusses the Challenger disaster and suggests that the people who made the decision to launch the rocket in 1986 should have been home sleeping in bed. Mr. Devine advised that students need to know that they will have decent lives if they go into science and technology fields. He stated he was bringing this to the Council's attention because the Council is a leadership committee. He added that some people feel there are too many STEM workers and others who feel that more will be needed doing more interesting work in a proper work/life balance.

Dr. Squyres thanked Mr. Devine for his comments. Dr. Squyres noted that the Council's reorganization included adding two new temporary ad-hoc task forces. One is on "Big Data" and the other is on "STEM Education."

No one else from the public expressed an interest in making comments or addressing the Council.

Adjournment

Dr. Squyres adjourned the meeting for the day at 5:00 p.m.

Thursday, April 17, 2014

Call to Order and Announcements

Ms. Rausch called the meeting to order at 9:00 a.m. She welcomed everyone back to day two of the NAC meeting. She reminded everyone that the Council meeting is a public meeting and that all comments, questions, and presentations will be on the record at all times. Meeting minutes will be prepared and will be posted to the NAC web site, www.nasa.gov/offices/nac, soon after the meeting.

Remarks by Council Chair

Ms. Rausch introduced Dr. Squyres. He reminded everyone to always use a microphone because the meeting is open to the public. He asked everyone on the phone line to mute their phones by pressing "star-6". The agenda was revised to move the Council discussion item to after the T&I Committee presentation. Three items must be covered during the discussion period. One is the new item on space debris. Mr. Young will present a new topic. The third item is to select dates and locations for the next two meetings.

Human Exploration and Operations Committee Report

Dr. Squyres introduced Mr. Kenneth Bowersox, Chair, Human Exploration and Operations (HEO) Committee. Mr. Bowersox reviewed the Committee's membership and the Committee's agenda from its last meeting. He presented the organization chart for the HEOMD. A report given to the Committee by the Research Subcommittee on the One-Year Study and Genome Project was discussed. Mr. Bowersox noted that the Research Committee had been established pursuant to a March, 2012 NAC recommendation to create a subcommittee that "... advises NASA on the research and educational needs that are required to support a plan for the long-range human exploration of space ...". He described the Research Subcommittee membership and its recent activities. A chart was presented on NASA's Space Life and Physical Sciences Research and Applications Division (SLPS). SLPS executes research and application activities in space biology, physical sciences, and human research. It serves as the Agency liaison with the Center for the Advancement of Science in Space (CASIS), which is the ISS National Laboratory management organization. The National Academy of Sciences (NAS) commissioned an NRC Decadal Survey on NASA Life and Physical Sciences. The NRC report serves as a guide to SLPS for developing applied and fundamental research that promotes the NASA human exploration mission. Mr. Bowersox presented a chart on Exploration biomedical challenges. The chart shows health and performance risks for the ISS, Lunar, Near Earth Asteroid, and Mars

missions. The One-Year Increment was described. American astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko will spend one year on the ISS. Astronaut Mark Kelly, Scott's twin brother, will remain on the ground and serve as a control subject for a Twins Study Investigation. Mr. Bowersox noted that the study would include the "gut stuff" and he presented a slide showing that the fields to be covered in the study are genomics, transcriptomics, epigenomics, proteomics, metagenomics, and metabolomics. Mr. Bowersox explained that the Russian partners are excited by new data acquisition methods that will be used in the study. A cargo capability with down mass for returning biological samples will be critical to the study.

Mr. Bowersox presented a proposed Finding that the Council endorses the genomic study. Dr. Squyres suggested that this should be a Committee finding directed to HEOMD's AA. Mr. Bowersox concurred. The Council approved the Finding as follows:

The Human Exploration and Operations (HEO) Committee endorses NASA's research initiatives that explore the genomic implications of spaceflight, including the proposed Twins Study and development of an open source approach for the Space Life and Physical Sciences GeneLab initiative. The Research Subcommittee of the HEO Committee will request regular updates to these initiatives at each of its next several meetings.

Mr. Bowersox discussed the program status on the ISS. He presented a summary chart showing flights planned to the ISS through 2015. The Soyuz-38 crew will be joining the Soyuz-37 crew already on orbit. The members on each crew were described. A slide was reviewed showing the Expedition 39 objectives. A chart showing an increase in crew work hours was discussed. Mr. Bowersox noted that working relations on the ISS between Russia and the U.S. remain great, notwithstanding the current international situation involving Ukraine. He explained that the people working on the ISS are used to dealing with "political noise." Mr. Bowersox discussed the ISS Top Program Risk Matrix. The three highest risks are lack of assured access to ISS, pension harmonization for a major contractor's retired employees, and ISS operations budget reductions. Mr. Bowersox briefed the Council on the Extra-Vehicular Activity (EVA) suit water infiltration investigation. Engineers still have not determined what caused the suit to fill with water, although silica accumulation from ion exchange beds is the prime suspect. A new EVA suit is to be flown to the ISS and the old one returned on SpaceX-3. In the interim, a water-absorption pad and a snorkel have been installed in the suit to mitigate against a possible reoccurrence. In response to a question from Dr. McComas, Mr. Hale explained that the U.S. owns 13 EVA suits and that a down mass transportation capability is important to return these EVA suits to Earth for refurbishment. In response to a question from Gen. Lyles, Mr. Bowersox responded that the water problem is unique to U.S. spacesuits and does not affect the Russian spacesuits. EVAs can still be performed. Mr. Bowersox described NASA's plans to conduct an EVA to remove and replace the failed MDM. He described two new investigations on Increment 39. One is a Vegetable Production System (VEGGIE), which will be the largest greenhouse ever flown in space. The other is T-Cell Activation in Aging, which is expected to help understand what causes a depression in the human immune system while in microgravity.

Mr. Bowersox discussed the CPC. A chart was presented showing CPC acquisition activities through 2017. He explained that the Commercial Crew Transportation Capability (CCtCap) objective is to develop and certify a Commercial Crew Transportation System (CTS) that can safely transport NASA crew to the ISS as soon as possible, with the goal of no later than 2017. It will be a phased acquisition using competitive down-selection procedures in a full and open competition in a firm-fixed-price, performance-based contract with a fixed-price Indefinite Delivery/Indefinite Quantity (ID/IQ) element. NASA is now in the Commercial Crew Integrated Capability (CCiCap) phase and has three partners with funded agreements: Boeing, SpaceX, and Orbital, and an unfunded agreement with Blue Origin. In response to a question from Dr. Squyres, Mr. Bowersox responded that there will be a down-select and that he trusts NASA to make the right decision. He added that it is great to see the diversity of vehicles now available in the program.

Mr. Bowersox reported that the HEO Committee had been briefed on the means for managing spaceflight programs and projects, with a focus on NASA Procedural Requirement (NPR) 7120.5E, which became effective on August 14, 2012. Charts were presented showing the steps in a Program's lifecycle and the different authorities involved in the process. He observed that while the NPR helps establish order and discipline, it makes it difficult for NASA's Program Managers (PMs) to do their job. Gen. Lyles remarked that it would be simpler for the contracting community if there was a uniform process across agencies.

The status of Exploration Systems Development (ESD) was discussed. NASA continues to make great progress with SLS, Orion, and GSDO. The three programs remain on track for the first integrated test flight, EM-1. Mr. Bowersox reported that the Committee had been briefed by Mr. Gerstenmaier on NASA's Human Exploration Strategy, and that the briefing was substantially similar to the briefing that Mr. Gerstenmaier had given to the Council the previous morning. He commented that it might be better to call it a framework or approach, rather than a strategy. Dr. McComas noted that science was not shown in the strategy. Mr. Bowersox acknowledged the omission and explained that Exploration without science is "just wandering around." Dr. Squyres observed that crew safety and mission success also were not shown in the strategy. Dr. McComas remarked that it was not good to see key items missing. Mr. O'Brien stated that public outreach is a key for sustainability. Mr. Hale advised that if zero crew loss is the requirement, then no Exploration mission should be undertaken because it is a high risk endeavor that is not 100% safe. He added that penny pinching along the way will lead to unsafe practices.

Mr. Bowersox described aspects of the Exploration Strategy that make it a viable and suitable approach. It allows for multiple paths to arrive at the same endpoint. The pacing changes as the budget changes. It incorporates participation by commercial endeavors and international partners. It allows for different exploration domains depending on available capabilities. It allows multiple types of interesting missions as funding is available. It shows how capability demonstration missions fit within the desire to establish a human presence in the Solar System independent from Earth. It has multiple possible destinations, including Mars.

Mr. Bowersox presented a proposed Council Finding to endorse NASA's Human Exploration Strategy. Dr. Kennel questioned whether Mr. Young, who had left the meeting, would accept the qualification in the strategy that there be a reasonable budget increase. Dr. Squyres counseled that this was very important because the strategy is a roadmap for the Agency's plans over the next few decades. Dr. Kennel remarked that the only weakness in the plan is the credibility of the funding statement. Dr. Austin noted her appreciation over the plan's clarity; however, she expressed concern that the plan calls for more money than Congress is willing to provide. She advised that the strategy should show what can be afforded and then show what could be done with additional funding. She explained it that it is better to show people what NASA thinks it can actually achieve. Mr. O'Brien recalled that the Agency has a long history about being unrealistic. Gen. Lyles concurred with Dr. Austin. He added that the proposed finding was too positive and needed to include a cautionary statement. Mr. Hale explained that he would endorse the finding; however, he is concerned about the flight rate and believes it can become a safety concern. Unfortunately, to increase the flight rate would require additional funds. Dr. Ballhaus expressed concern that the low flight rate would adversely affect the mission and safety. Ms. Blakey recommended that a sentence be added to the Finding to address the concern over the budget. Ms. Schmoll advised that funds are needed to achieve the goal. Dr. Squyres noted that the strategy does not take into account the high probability that the budget will be flat in the future. Gen. Lyles advised that the strategy needs to be explained by a narrative in order to be well-received by the general public. Dr. Kennel suggested that a "stress test" be used to determine the point at which the strategy would break. Dr. Squyres counseled that this is the most important issue faced by the Agency. He believes that the strategy is the best articulation for a long-term strategy that he has heard during his tenure as Council Chair; he has not, however, heard a Council consensus to approve the Finding. He suggested that the proposal be tabled and addressed at the next Council meeting. Mr. Bowersox concurred.

Dr. Squyres thanked Mr. Bowersox for his presentation.

Technology and Innovation Committee Report

Dr. Squyres introduced Dr. William Ballhaus, Chair, Technology and Innovation Committee. Dr. Ballhaus reviewed the Committee's participants and the Committee's agenda from its last meeting. He reminded the Council that the Committee's scope includes all NASA programs that could benefit from technology, research, and innovation. Dr. Ballhaus remarked that it is alarming to see what had happened to the NASA space technology program over the years until recently. He described how the technology program was reestablished. There is now a Chief Technologist, Mr. David Miller, who has a seat at the Administrator's table. In addition, there is a separate directorate for space technology, STMD, headed by AA Dr. Michael Gazarik, who has done an excellent job. Dr. Ballhaus noted that NASA's previous Chief Technologist, Dr. Mason Peck, had promulgated a definition for Technology as follows: *A solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem, to enable a specific capability.* The definition had been used by Dr. Peck to demonstrate the need for NASA to establish a basic research program. As a result, the Council had issued a

recommendation that NASA establish a basic research program. Dr. Ballhaus reported that a \$10 M program for this purpose, the Foundational Engineering Services (FES), has been established by NASA and will be managed by STMD. Dr. Ballhaus remarked that that was a reasonable response by the Agency. Gen. Lyles observed that the primary focus for the research program is space and that Aeronautics does not appear to be included, notwithstanding the synergism between Aeronautics and space technology.

Dr. Ballhaus presented a slide showing how space technology is an investment for the future. The Space Technology Program (STP) is reestablishing opportunities for graduate and doctoral students. He presented a slide delineating the program's portfolio into three categories: transformative and crosscutting technology breakthroughs, pioneering concepts and developing the innovation community, and creating markets and growing the innovation economy. Major highlights from the STP were reviewed. NASA is preparing to send its fifth in a series of smartphone-controlled small spacecraft into orbit. PhoneSat 2.5 is scheduled to launch on the next SpaceX commercial cargo flight to the ISS. A 5.5 meter composite cryogenic propellant tank has been successfully fabricated. NASA engineers have successfully tested a 3-D printed rocket engine injector, marking a first step in using additive manufacturing for space travel. The injector part typically takes six months to fabricate at a cost of more than \$10,000. It was fabricated in three weeks for under \$5000 using the new process. Dr. Ballhaus noted that there are predictions that additive manufacturing will be a \$5.2 B industry by 2020. A chart was presented showing NASA's vision for in-space manufacturing technology development through 2040. It was noted that advanced manufacturing is critical to all NASA mission areas.

The SPHERES-Slosh investigation was described. It uses small robotic satellites on the ISS to examine how liquids move inside containers in microgravity. Low density supersonic decelerator parachute testing at China Lake in California was successfully demonstrated. New high-tech legs have been developed for the ISS's Robonaut 2. A chart was presenting showing eight key thrust areas that will enable or substantially enhance future NASA mission capabilities. Space technology will focus investments in these eight areas. They are: high-power solar electric propulsion (SEP), space optical communications, advanced life support and resource utilization, Mars entry, descent and landing systems, space robotics systems, lightweight space structures, deep space navigation, and space observatory systems. Dr. Ballhaus reviewed the STMD FY 2015 President's Budget. He noted that the line item for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs distorts the budget for technology when across-the-board budget cuts are made. This is because SBIR and STTR are generally held harmless from being affected by those cuts.

Dr. Ballhaus discussed the Green Propellant Infusion Mission (GPIM). This is a Technology Demonstration Mission developed in a public/private partnership to demonstrate and test the capabilities of a high-performance, non-toxic, "green" fuel on orbit. This the first time the nation will use a spacecraft to test green propellant technology. A non-toxic fuel is much easier to use and handle than ordinary fuel, leading to significant cost savings. Dr. Ballhaus described the Deep Space Atomic Clock. It is a technology success and provides unprecedented stability needed for next-generation deep space navigation and radio science.

A chart showing how the ARM provides capabilities for deep space and Mars missions was presented. Dr. Ballhaus reviewed charts showing STMD investments to advance future capabilities of SLS and Orion, to advance human exploration of Mars, and to advance outer planet exploration. The Small Spacecraft Technology Program was described.

Dr. Ballhaus presented a proposed Committee Finding for the STMD AA, which after Council deliberation was changed to a Recommendation to the STMD AA:

The Technology and Innovation Committee recommends that STMD characterize the small spacecraft mission market pull:

- Civil, military, intelligence, commercial, academia
- What is the technology's potential utility and societal benefits?

The Technology and Innovation Committee further recommends that STMD identify what is NASA's particular role in developing capabilities for this market. How can NASA "move the needle?"

Gen. Lyles noted that market pull is critical and involves many players; he suggested asking the NRC to study this question. In response to a question from Dr. Squyres, Dr. Ballhaus clarified that the findings are actually intended to be the reasons for the recommendation. The recommendation was approved by the Council; however, Dr. Squyres and Dr. Ballhaus agreed, with Ms. Rausch's assistance, to reformulate the recommendation into the Council's standard format after the meeting.

Dr. Ballhaus presented a proposed Committee finding for the STMD AA that it is important for the STMD to maintain a balanced portfolio across all Technology Readiness Levels (TRL)-levels during the coming budget deliberations. After discussion, it was agreed to table this finding so that it can be restated.

Dr. Ballhaus presented a proposed Council recommendation that the STMD and SMD AA's investigate how to encourage the infusion of new technologies in small to medium class missions. He explained that proposals with risk are penalized when evaluated. This leads to a disincentive to proposed new technology. Dr. McComas explained that there are advantages and disadvantages to the proposed recommendation. He noted that "small and medium" means the Explorer Program. Dr. Squyres noted that the Explorer Program is capped at \$1 B, while the Discovery Program is capped at \$5 B. He explained that he agrees with the recommendation; however, the recommendation should be discussed by both the T&I Committee and the Science Committee. The recommendation was tabled and jointly assigned to the two committees.

Dr. Squyres thanked Dr. Ballhaus for his presentation.

Council Discussion

As a follow-up to an issue raised by Dr. Austin on the first day of the Council's meeting, Dr. Squyres read into the record a statement prepared by Dr. Austin and Dr. Kennel on the problem posed by space debris.

Space debris poses a "known unknown" risk to operational satellites and ISS safety. What is known is that there is a significant amount of debris already; and that, with the increasing number of space-faring nations and utilization of space for civil, commercial and military applications, the risk of collision with space debris will continue to grow. NASA has an opportunity for increasing its leadership role by providing the global space community with baseline information about debris (small) that is currently in orbit, how the debris field is changing with time, and how it is forecasted to change. The Orbital Debris Engineering Model (ORDEM) maintained by NASA can be used to address this problem. NASA has also led the international community, through the Inter-Agency Space Debris Coordination Committee (IADC), in the development of guidelines for debris mitigation that have been adopted by the Federal Aviation Administration and Federal Communications Commission.

Questions for Discussion:

- 1. What are the current NASA efforts to address the risks of space debris to operational satellites in general and ISS in particular?*
- 2. What should be NASA's role in establishing policy and standards for addressing the space debris threat? How does NASA participate in the relevant national and international policy forums?*
- 3. What proactive actions could be initiated to slow the growth of space debris?*
- 4. What is the current status of NASA's capability to measure, track, and model small items of debris that are not tracked or catalogued by the AF JSPoC? Do they pose a threat to NASA and other U.S. operational spacecraft?*
- 5. To what extent has awareness of the developing space debris risk influenced the planning for extended ISS operations and reentry?*

Proposed Action:

Request that the Meteorite and Orbital Debris Program Office (Johnson Space Center?) be invited to a NAC meeting to provide an update on current activities for capturing and modeling debris data and for mitigating debris. Request also a briefing on NASA's participation in space debris policy forums.

Dr. Austin reported that not enough is known to recommend an action. She suggested that it would be more valuable to give NASA the opportunity to inform the NAC on current activities, capabilities, and activities. After that briefing, the NAC would be better able to formulate a recommendation and explain the impact of no action. Dr. Squyres agreed to establish an agenda item for the Council to be briefed on space debris at an upcoming Council meeting. Dr. Kennel requested Ms. Rausch to provide the Council with a recent NRC report on the issue.

Dr. Squyres noted that Mr. Young has suggested a new item for the Council's consideration at its next meeting. It is a proposed recommendation to subject the ARM concept to an independent non-advocacy estimate for the mission once the Agency has settled upon whether its technical approach would be to grapple a small asteroid or to lift a boulder from a much larger asteroid. Also, at the next meeting, the Council will consider issuing a finding or recommendation on the Exploration Strategy, including budget concerns and concerns over flight rate and safety. The HEO Committee will review the issue first.

Ms. Blakey presented two proposed Recommendations for the NASA Administrator. These had been presented the previous day and had been revised overnight by Ms. Blakey pursuant to the Council's request. The first revised Recommendation addressed collaboration with DOD and DARPA, and was approved by the Council as follows:

The Council endorses NASA-DOD/DARPA collaboration on programs of mutual interest and recommends that NASA engage DOD/DARPA leadership to identify and explore opportunities where commercial technology can benefit future military missions and/or where military technologies can benefit civil and commercial applications. Current technology areas of mutual interest include (but are not limited to) hypersonic flight, autonomous/unmanned air systems, vertical lift technology, rocket propulsion development, collaborative vehicle operations for enhanced airspace/mission management, and related data analysis tools.

The second revised Recommendation addressed providing support for UTM, and was approved by the Council as follows:

The Council recommends that in order to safely enable widespread civilian Unmanned Aerial System (UAS) operations at lower altitudes, advanced research and prototyping of an Air Traffic Management (ATM)-like system is needed. NASA is currently exploring the function design, concept and technology development for such a prototype UAS Traffic Management (UTM) system. The Federal Aviation Administration (FAA) and a number of partners have expressed an interest in working with NASA in exploring the research, development, prototyping, testing and possible implementation of such a system. The Council recommends that the NASA Administrator and all NASA organizations involved in the development and sustainment of agreements and partnerships be proactively engaged in reducing implementation barriers and provide any necessary tools to enable the innovative partnerships that will be required for the realization of UTM. NASA should make this a high priority for the Agency given the urgency warranted by such a system.

Dr. Squyres thanked Ms. Blakey for her efforts.

The Council discussed proposed dates and locations for future Council meetings. It was tentatively decided to meet as follows:

- Week of July 28, 2014 – NASA Langley Research Center
(NAC Annual All Hands Meeting)
- December 8-9, 2014 – NASA Stennis Space Center
- April 8-9, 2015 – NASA Headquarters

NASA Early Career Scientist/Engineer Presentation: 21st Century Problem Solving Approaches at NASA: Challenges, Prizes, Crowdsourcing and Citizen Science

Dr. Squyres introduced Ms. Jennifer Gustetic, Prizes and Challenges Program Executive, Office of Chief Technologist, NASA HQ. Ms. Gustetic described how NASA is using prizes and challenges for innovation. She reported that it is a new way of doing business at NASA and is designed to tap the potential of millions of individuals using new legal authorities and on-line tools to accomplish NASA's missions. The NASA Centennial Challenges Program was described. It has been experimenting with prizes since 2008. Ms. Gustetic noted that using

prizes to incentivize change and technological development is not new. She referred the Council to a book entitled *Longitude*, about a prize offered in the early 1700s by the British Parliament to the first person who came up with a way to determine longitude for navigational purposes. Prizes, she observed, are newly in vogue and more useful. Dr. Squyres observed that the Northwest Passage was also incentivized by a prize.

Ms. Gustetic noted that NASA is leading the way in using prizes and challenges. The White House Office of Science and Technology Policy, in its *2012 Report to Congress on Government Prize Use*, states: "From the Centennial Challenges Program, to the NASA Open Innovation Pavilion, to the NASA Tournament Lab, NASA leads the public sector in the breadth and depth of experience and experimentation with prizes and challenges."

Ms. Gustetic explained that prizes and challenges have many advantages. They:

- Shine a spotlight on a problem or opportunity
- Are awarded only for results
- Explore a wide breadth and depth of potential solutions
- Target an ambitious goal without predicting which team or approach is most likely to succeed
- Reach beyond usual suspects to tap top talent
- Stimulate private sector investment many times greater than the prize purse
- Bring out-of-discipline perspectives to bear
- Inspire risk-taking by offering a level playing field

Ms. Gustetic described the NASA Tournament Lab that NASA and Harvard University have established. It uses capabilities of the TopCoder community for competitions to create the most innovative, most efficient, and most optimized solutions for specific, real-world challenges being faced by NASA researchers. She explained that although prizes, challenges, and crowdsourcing are not right for solving every problem, they can be transformative for the right problem and are another tool in NASA's toolkit for solving problems. They have encouraged new businesses to enter the emerging space industry. She described an event where a winning contestant constructed an autonomous, unmanned, remote-controlled quadcopter in 48 hours and then turned that experience into a successful business.

Dr. Squyres remarked that the key to using crowdsourcing well is the original decomposition of the problem. Ms. Gustetic agreed. She gave one hypothetical example where a hybrid combination of a pro golfer hitting drives and a crowd doing the putting would produce the best low ball score in golf. Dr. Ballhaus asked whether crowdsourcing has been used as an approach to independent verification and validation of software. Ms. Gustetic responded that she was not sure and that there may be issues with respect to International Traffic in Arms Regulations (ITAR).

Ms. Gustetic described a crowdsourcing success in finding a way to diagnose the cause of vision loss suffered by astronauts that may be due to intra-cranial pressure changes. It is hard to measure those changes non-invasively. An incentive challenge produced an algorithm-based approach using other measurements and data sets for determining the pressure changes. Another success was the development of improved gloves for spacesuits. A sample glove was circulated.

Dr. Squyres reported that he had heard anecdotally that contestants invest significantly more than they stand to gain. Ms. Gustetic responded that a rough rule of thumb is to target the purse at about 80 percent of what a prototype should cost.

Ms. Gustetic described the NASA Technology Transfer Portal at <http://technology.nasa.gov>. The Portal contains data from HQ and all 10 NASA Field enters, enabling industry and the general public to find information about technology opportunities, licensing opportunities, and past success stories. At another website, marblar.com/nasa, crowdsourcing is used to find new uses for NASA's new technologies and to match "ideators" with commercial partners. She described <http://www.diskdetective.org>, where NASA is inviting the public to help astronomers discover embryonic planetary systems hidden among data from the Agency's Wide-field Infrared Survey Explorer (WISE) mission. In a challenge at <http://www.topcoder.com/asteroids/asteroiddatahunter>, NASA is tasking competitors with developing a significantly improved algorithm to identify asteroids in images from ground-based telescopes. In another challenge, at <https://2013.spaceappschallenge.org/challenge/cubesats-for-asteroid->

exploration, participants are asked to develop a website that publicizes potential interplanetary destinations for CubeSat missions and available launch opportunities. She referred to Jeremiah Owyang's blog, at <http://www.web-strategist.com/blog>, which since 2004 has been listing companies that use crowd techniques and are now business models.

In response to a question from Gen. Lyles, Ms. Gustetic informed the Council that she had studied aerospace engineering at the University of Florida, studied Technical Policy at the Massachusetts Institute of Technology, and that she has been working at NASA for two years. Mr. O'Brien told Ms. Gustetic that "you win," and that the direction she has been speaking about is the direction where NASA should be heading. He asked whether she had any ideas on how the Council can assist her. She responded that it would be helpful for the Council to think about the types of problems that can be well-suited to the methods she has discussed. Also, more could be done if there was more money for the challenges. In response to a question from Ms. Blakey, Ms. Gustetic explained that NASA is not permitted to raise funds from outside sources. The problem is the Anti-Deficiency Act. She expressed appreciation to a "very innovative" NASA's Office of General Counsel that is helping to navigate that act. Dr. Squyres thanked Ms. Gustetic for her presentation and the Council applauded her for her efforts.

Council Discussion; Wrap-up; Final Acknowledgments

Dr. Squyres invited the Council members to engage in an open discussion on any subject. Dr. Austin remarked that she appreciated the focus on providing the Administrator with actionable feedback. Mr. Hale advised that there is a need to work on the narrative that explains to the man in the street "why" humans should go to Mars. Dr. Squyres noted that the Exploration Strategy will be an important focus at the next Council meeting and that there is a need to find a way to make it compelling to the people who are paying for it. Ms. Schmoll advised that the budget is the primary challenge. Mr. O'Brien suggested that the Council should encourage the Administrator to unleash NASA employees because they have the enthusiasm and passion to accomplish great things. Ms. Blakey observed that NASA is adapting well to the times and to the budgetary constraints. She added: "That does not mean that we shouldn't kick against the bricks." Dr. Kennel noted that the NRC was about to issue a report on the rationales for human spaceflight. Gen. Lyles counseled that there are many IT and IT security events going on elsewhere that the Council can learn from. Dr. McComas explained that any business would do market research before finalizing a message and selling it. NASA needs to hone its message. He is concerned that the Council may be hearing the message differently than it is being heard by the public. He suggested that Ms. Gustetic may be able to help with that. Mr. Bowersox commented that being allowed now to talk about Mars is an important change. Gen. Lyles noted that a soon-to-be-released, Congressionally-mandated NRC study on human spaceflight covers public outreach. He will assist Ms. Rausch in making it available to the Council members.

Dr. Squyres again noted that this was Dr. Kennel's final NAC meeting, and thanked Dr. Kennel for his tireless service to the Nation's space program. He thanked the new Council members for their willingness to serve and he thanked the existing Council members for their willingness to continue to serve. Applause was given to the NAC support staff, Ms. Rausch and minute-taker Mr. David Frankel, for their assistance to the Council. Dr. Squyres asked the Council members to plan well for the next meeting because the meeting at Langley will be the most important meeting that the Council has had during his tenure as its Chair. There should be a focus on the advice that can be given on the Exploration Strategy and the advice must be implementable. He cautioned the Council that it cannot advise the Administrator not to go to Mars.

Adjournment

Dr. Squyres adjourned the meeting at 12:30 p.m.

NASA ADVISORY COUNCIL

**NASA Headquarters
Program Review Center (Room 9H40)
Washington, DC 20546**

PUBLIC MEETING**April 16-17, 2014****Wednesday, April 16, 2014**

9:00 – 9:03 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA Headquarters
9:03 – 9:10 am	Opening Remarks by Council Chair	Dr. Steven W. Squyres Chair, NASA Advisory Council
9:10 – 10:00 am	Remarks by NASA Administrator	Mr. Charles F. Bolden, Jr. NASA Administrator
10:00 – 10:40 am	The Administration's Vision for NASA	Dr. John P. Holdren President's Science Advisor Director, Office of Science and Technology Policy The White House
10:40 – 11:00 am	Break	
11:00 am – 12:00 noon	NASA Human Spaceflight Update; Asteroid Initiative Update	Mr. William Gerstenmaier Associate Administrator for Human Exploration and Operations Mission Directorate NASA Headquarters
12:00 – 1:30 pm	Lunch	
1:30 – 2:30 pm	President's FY 2015 Budget Request For NASA	Dr. Elizabeth (Beth) Robinson Chief Financial Officer NASA Headquarters
2:30 – 3:15 pm	Council Discussion	
3:15 – 4:00 pm	Aeronautics Committee Report	Ms. Marion Blakey, Chair
4:00 – 4:45 pm	Science Committee Report	Dr. David McComas, Chair
5:00 pm	Adjourn	

Thursday, April 17, 2014

9:00 – 9:01 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA Headquarters
9:01 – 9:03 am	Remarks by Council Chair	Dr. Steven W. Squyres Chair, NASA Advisory Council
9:03 – 9:45 pm	Human Exploration and Operations Committee Report	Mr. Kenneth Bowersox, Chair
9:45 – 10:15 am	Council Discussion	
10:15 – 11:00 am	Technology and Innovation Committee Report	Dr. William Ballhaus, Chair
11:00 am – 12:00 noon	NASA Early Career Scientist/Engineer Presentation – 21 st Century Problem Solving Approaches at NASA: Challenges, Prizes, Crowdsourcing and Citizen Science	Ms. Jennifer Gustetic Program Executive Office of Chief Technologist NASA Headquarters
12:00 noon – 12:30 pm	Council Discussion; Wrap-up; Final Acknowledgments	
12:30 pm	Adjourn	

NASA ADVISORY COUNCIL

Membership – April 2014

Role	Council Members
Chair – NASA Advisory Council	Dr. Steven Squyres , <i>James A Weeks Professor of Astronomy, Cornell University</i>
Member at Large	Dr. Wanda M. Austin , <i>President and CEO, The Aerospace Corporation</i>
Member at Large	Mr. N. Wayne Hale , <i>Consultant, Special Aerospace Services; NASA (Ret.)</i>
Member at Large	Prof. G. Scott Hubbard , <i>Department of Aeronautics and Astronautics, Stanford University</i>
Member at Large	Mr. Miles O'Brien , <i>Independent Journalist</i>
Member at Large	Mr. A. Thomas Young , <i>Lockheed Martin (Ret.); Former Director, NASA Goddard Space Flight Center</i>
Chair – Aeronautics Committee	The Honorable Marion Blakey , <i>President and CEO, Aerospace Industries Association</i>
Chair – Human Exploration and Operations Committee	Mr. Kenneth Bowersox , <i>U.S. Naval Aviator (Ret.); Former NASA Astronaut</i>
Chair – Science Committee	Dr. David J. McComas , <i>Assistant Vice President, Space Science and Engineering Division, Southwest Research Institute</i>
Chair – Technology and Innovation Committee	Dr. William F. Ballhaus Jr. , <i>President and Chief Executive Officer (Ret.), The Aerospace Corporation</i>
Chair, Institutional Committee	Ms. Kathryn Schmoll , <i>Vice President, Finance and Administration, University Corporation for Atmospheric Research</i>
Ex-Officio Members	Gen. Lester Lyles , <i>Chair, Aeronautics and Space Engineering Board, National Academies; United States Air Force (Ret.)</i> Dr. Charles F. Kennel , <i>Chair, Space Studies Board, National Academies of Sciences; Director and Distinguished Professor Emeritus, Scripps Institution of Oceanography, University of California, San Diego</i>

NASA ADVISORY COUNCIL
NASA Headquarters
Washington, DC
April 16-17, 2014

MEETING ATTENDEES

NASA Advisory Council Members:

Dr. Steven W. Squyres, <i>Chair</i>	Cornell University
Dr. Wanda Austin	The Aerospace Corporation
Dr. William Ballhaus	The Aerospace Corporation (Ret.)
Ms. Marion Blakey	Aerospace Industries Association
Mr. Ken Bowersox	U.S. Navy (Ret.)
Mr. N. Wayne Hale	Special Aerospace Services
Dr. Charles Kennel (<i>Ex Officio</i>)	Space Studies Board, National Academy of Sciences
Gen. Lester Lyles (<i>Ex Officio</i>)	Aeronautics and Space Engineering Board
Dr. David McComas	National Academy of Engineering
Mr. Miles O'Brien	Southwest Research Institute
Ms. Kathryn Schmoll	Independent Journalist
Mr. A. Thomas Young	University Corporation for Atmospheric Research
	Lockheed Martin (Ret.)
Ms. P. Diane Rausch, <i>Executive Director</i>	NASA Headquarters

NASA Attendees:

Bell, Hal	NASA HQ
Bolden, Charles	NASA HQ
Condes, Al	NASA HQ
Cotes, Michelle	NASA HQ
Feeley, T. Jens	NASA HQ
French, Mike	NASA HQ
Gerstenmaier, William	NASA HQ
Green, Mike	NASA HQ
Gustetic, Jennifer	NASA HQ
Irving, Rick	NASA HQ
Jacobs, Bob	NASA HQ
Kamm, Shari	NASA HQ
Kapinski, Amy	NASA HQ
Kelly, Allison	NASA HQ
Kessler, Jason	NASA HQ
King, Marla	NASA HQ
MacDonald, Alex	NASA/JPL
McKay, Meredith	NASA HQ
Miller, David	NASA HQ
Minor, Susan	NASA HQ

Mullins, A. Todd
Nelson, Elise
Palmer, Jennifer
Robinson, Beth
Robinson, Shawanda
Siegel, Bette
Stofan, Ellen
Weaver, David

NASA HQ
NASA HQ
NASA HQ
NASA HQ
NASA HQ
NASA HQ
NASA HQ
NASA HQ

Other Attendees:

Bardi, Francisco
Berron, Kreston
DalBello, Richard
Divine, Charles
Frankel, David
Goldstein, Ed
Hendrickson, Dan
Holdren, John
Karanian, Linda
Lane, Carol
Larson, Phil
Leone, Dan
Moloney, Michael
Oschmann, Jim
Smith, Marcia
Uhran, Bergit

The Aerospace Corporation
Orbital
Office of Science & Technology Policy (OSTP)
Metro Washington Mensa
PB Frankel, LLC
Aerospace Industries Association (AIA)
AIA
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National Research Council
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PB Frankel, LLC

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LIST OF PRESENTATION MATERIAL

- 1) NASA's Exploration Strategy [Gerstenmaier]
- 2) Fiscal Year 2015 Budget Estimates [Robinson]
- 3) Aeronautics Committee Report [Blakey]
- 4) Science Committee Report [McComas]
- 5) Human Exploration Committee Report [Bowersox]
- 6) Technology and Innovation Committee Report [Ballhaus]
- 7) 21st Century Ways of Doing Business at NASA: Prizes, Challenges and Crowdsourcing [Gustetic]